University of Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: PET 535: MODERN WELL DESIGN

DATE: MAY 22 , 2018

TIME: 0900 - 1300

AID: CALCULATOR

THE EXAM CONSISTS OF 5 PROBLEMS AND 5 PAGES

REMARKS: PLEASE STATE ASSUMPTIONS

Problem 1|: Design of liner and tieback string

An HPHT well is drilled. The formation evaluation is positive and recommends flow testing of the well. A tieback string is therefore installed in the well. Other data are:

Liner interval:	4650 m-5100 m (well bottom)
Tie-back interval:	4650 m- 0
Top cement:	4650 m
Depth of test packer:	4950 m
Mud weight:	2.2. s.g.
Pore pressure:	2.11 s.g. at 5000 m
Density of reservoir fluid:	0.547 s.g.

Data for the liner and tie-back string:
7-5/8 in. SMC 110

Weight in air:	625 N/m
Burst resistance:	1005 bar
Collapse resistance:	959 bar
Tensile strength:	6816 kN

Yield factor reduction due to temperature: 0.91

a) Prepare a figure and write all assumptions.

b) Define a realistic collapse scenario for the liner. Derate strength to 88% level because of high temperature. Determine the design factor.

c) Define two burst criteria. Determine the design factor for burst, and correct for temperature.

d) Define a criterion for tension design. Determine the design factor, including the temperature derating.

Problem 2: Wellbore friction

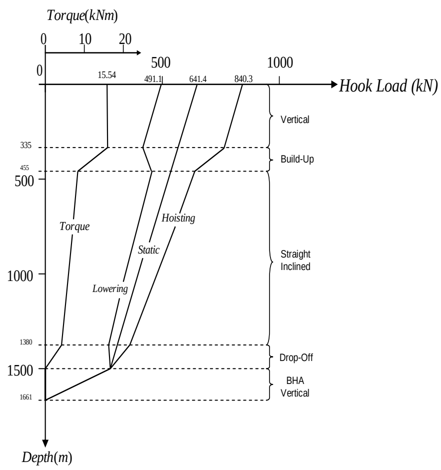
The enclosed figure shows hookload data for a deviated well.

a) By inspection of the force plot, suggest the type of well geometry for each of the four distinct intervals.

b) In a long deviated well titanium drillpipe will be used for half of the well length. Would you use the titanium pipe in the top or in the bottom part of the well. Why?

c) The oil industry uses a stuck pipe model that does not include friction. Will the depth to the stuck point be too shallow or too deep using this model?

d) Static pipe weight without friction is defined by "the projected height principle". Prepare a figure of an inclined pipe element, show the forces and derive this principle.



Problem 3: Geomechanics

a) Show an expression for the horizontal in-situ stress. How would you select the mudweight relative to this? What do we call this concept?

b) Three LOT data sets are given in a well as follows:

Depth(m):	LOT(s.g.):	Pore(s.g.):	Overburden(s.g.):	Inclination():
890	1,51	1,03	1,62	0
1124	1.35	1.21	1.76	30
1540	1,27	1,30	1,80	39

Estimate the LOT values for vertical hole sections.

c) Compute the horizontal stress levels from the data above.
State all assumptions.

Problem 4. Hydraulics

a) In the hydraulic system of the drilling rig, is the flow mostly laminar or mostly turbulent? Provide you answer with an example.

b) Which parameter contributes mostly to the pressure drop, viscosity or density of the drilling fluid? Explain.

c) Comparing ordinary rotary drilling with drilling with a motor, are there any differences? If yes, identify one important difference.

d) The drill string is changed from 3.5 in to 5 in in a well. Identify three improvements in the hydraulic system.

e) Define an equation for mechanical power and one for hydraulic power. Define the variables.

Problem 5: Data normalization

You are planning a subsea infill well in a production field. Your design is based on data from the production platform which has a wellhead elevation of 120 m. You are going to use a jackup drilling rig with a air gap of 40 m. The water depth is 300 m. The data from the production platform are:

Pore press. Grad.(sg)	0.82	0.90	0.95	1.10	1.15	1.20
Depth(m)	500	700	900	1100	1300	1500

a) Define the normalization equations.

b) Normalise the pore pressure gradient to drillfloor level and sea level. Show all three curves in a plot.

c) Connect each data point with a curve for the three reference levels. Explain the meaning of this curve. What do we call this curve.

Some Formulas

P(bar) = 0.098 x d(s.g.) x D(m)

$P3 = Cq^m$

$P2 = \rho q^2/2A^2 0.95^2$

Index:	Equation:	Criterion:	Fraction parasitic pressure loss:	Flow rate:
1	$qP2$	Max. HP	1/(m+1)	P1/C(m+1)
2	$q\sqrt{P2}$	Max. jet impact	2/(m+2)	2P1/C(m+2)
3	$q^{3/2}\sqrt{P2}$	New A	3/(m+3)	3P1/C(m+3)
4	$q^2\sqrt{P2}$	New B	4/(m+4)	4P1/C(m+4)
5	$q^{5/2}\sqrt{P2}$	New C	5/(m+5)	5P1/C(m+5)

$A = q\{\rho/2P_2\}^{1/2}/0.95$

Using the units of: density(kg/l), flowrate (l/min) and pressure (bar), the nozzle area in in^2 can be obtained by dividing the equation above with 122.4.

$d_{RKB1} = d_{RKB2}D/(D-\delta h)$

$LOT = 2\sigma_a - P_o$

$P_{wf}(\gamma) = P_{wf}(0) + {}^{1/3}(P_o - P_o^*)\sin^2\gamma$

$P_{wf}(0) = \{P_{wf}(\gamma) + (\sigma_o - {}^{1/2}P_o)\sin^2\gamma\}/\{1 + {}^{1/2}\sin^2\gamma\}$

$\Delta\sigma_a = \Delta P_o(1-2\nu)/(1-\nu)$

$\Delta P_{wf} = \Delta P_o(1-3\nu)/(1-\nu)$

$P_{burst} = 2\sigma_{tensile}\, t/D_o$

$P_{collapse} = \{2CE/1 - \nu^2\}\{1/(D_o/t - 1)^2 D_o/t\}$

$(\sigma_t/\sigma_{yield}) = 1/2(\sigma_a/\sigma_{yield}) +/- \{1 - 3/4(\sigma_a/\sigma_{yield})^2\}^{1/2}$

$\rho = (d_p D - 1.03h_w)/(D - h_f - h_w)$

$$d_{wf2} = d_{wf1}\frac{D_1}{D_2} + d_{sw}\frac{D_{w2} - D_{w1}}{D_2}$$

$$D_2 = D_1 + (D_{w2} - D_{w1}) + (D_{f2} - D_{f1})$$

$$D_2 = D_1 + \left(D_{w2} - D_{w1}\right) + \left(D_{f2} - D_{f1}\right) + \left(\frac{d_{ob1}}{d_{ob2}} - 1\right)\left(D_1 - D_{w1} - D_{f1}\right)$$

$$\frac{\Delta V}{V} = \frac{1}{2}\alpha \Delta T$$

$$\Delta P = \left(\frac{-1}{c}\right)\frac{\Delta V}{V}$$

$$I_1 = \sigma_x + \sigma_y + \sigma_z$$

$$I_2 = \tau_{xy}^2 + \tau_{xz}^2 + \tau_{yz}^2 - \sigma_x\sigma_y - \sigma_x\sigma_z - \sigma_y\sigma_z$$

$$I_3 = \sigma_x(\sigma_y\sigma_z - \tau_{yz}^2) - \tau_{xy}(\tau_{xy}\sigma_z - \tau_{xz}\tau_{yz}) + \tau_{xz}(\tau_{xy}\tau_{yz} - \tau_{xz}\sigma_y)$$

$$J_1 = 0$$

$$J_2 = \frac{1}{6}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_1 - \sigma_3)^2 + (\sigma_2 - \sigma_3)^2\right]$$

$$J_3 = I_3 + \frac{1}{3}I_1 I_2 + \frac{2}{27}I_1^3$$

Units

1 bar = 14.5 psi = 10^5 Pa
1 ft = 0.3048 m = 12 in
1 lb_f = 0.454 kp = 4.45